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(54) Vacuum cleaner with dirt sensor

(57) A vacuum cleaner 10 is provided with a sensor 20 responsive to interaction between suction duct 14 and the dirt flowing therethrough to produce an electrical signal representative of the dirt within the airflow in the duct. The sensor, which may be secured to the exterior surface of the duct, may detect acoustical and/or mechanical vibrations or electrostatic charge. The electrical signal may be fed to a control module 21 for controlling the operation of motor 26 e.g. its speed and activating indicator light 23. The cleaner may be of the upright or cannister type. The sensor may be located at other positions along the dirt flowpath through the cleaner.

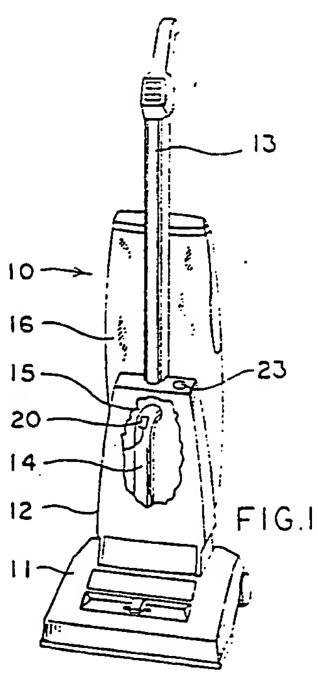

FIG.1

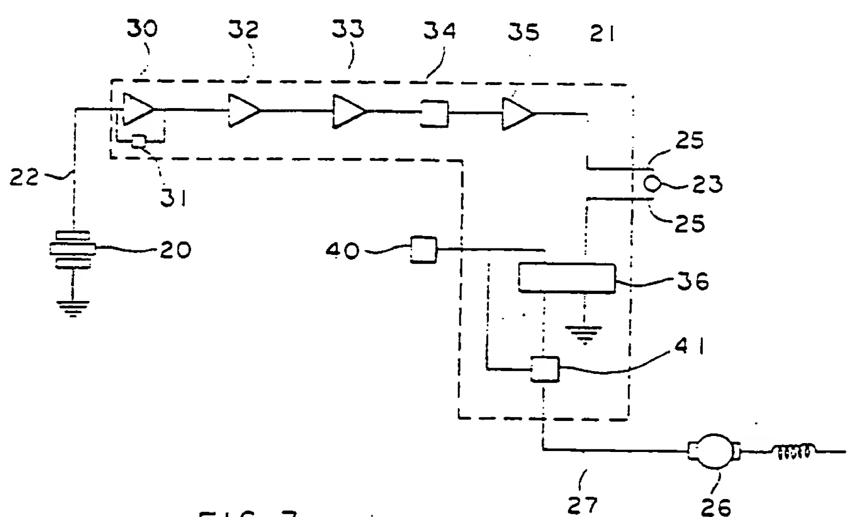

FIG.3

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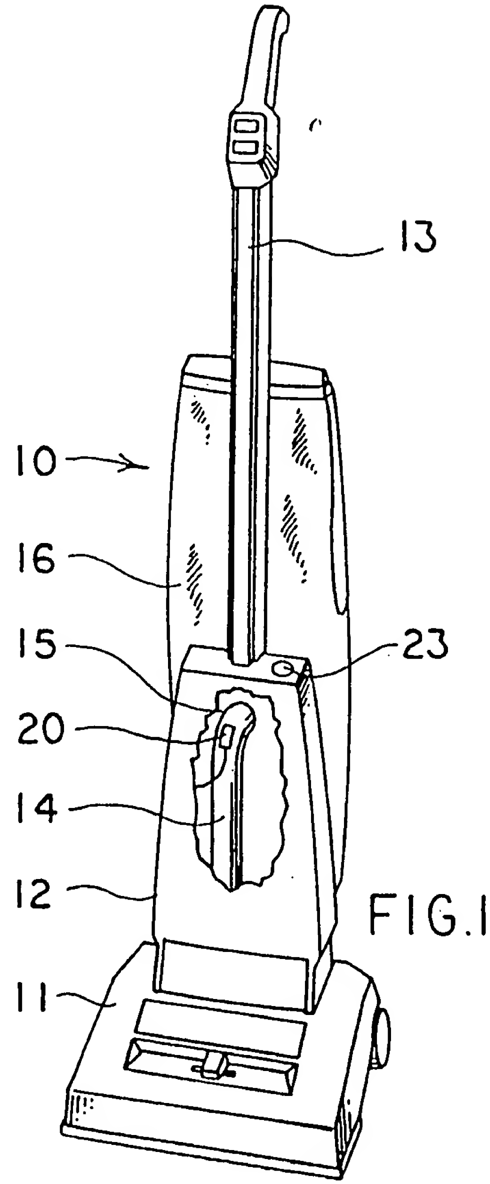

FIG.1

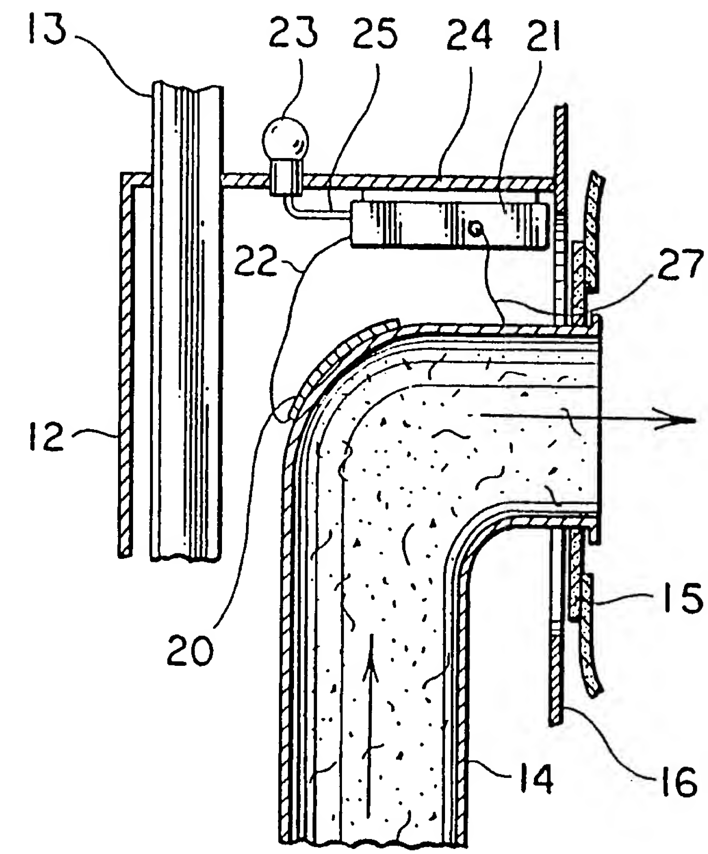

FIG.2

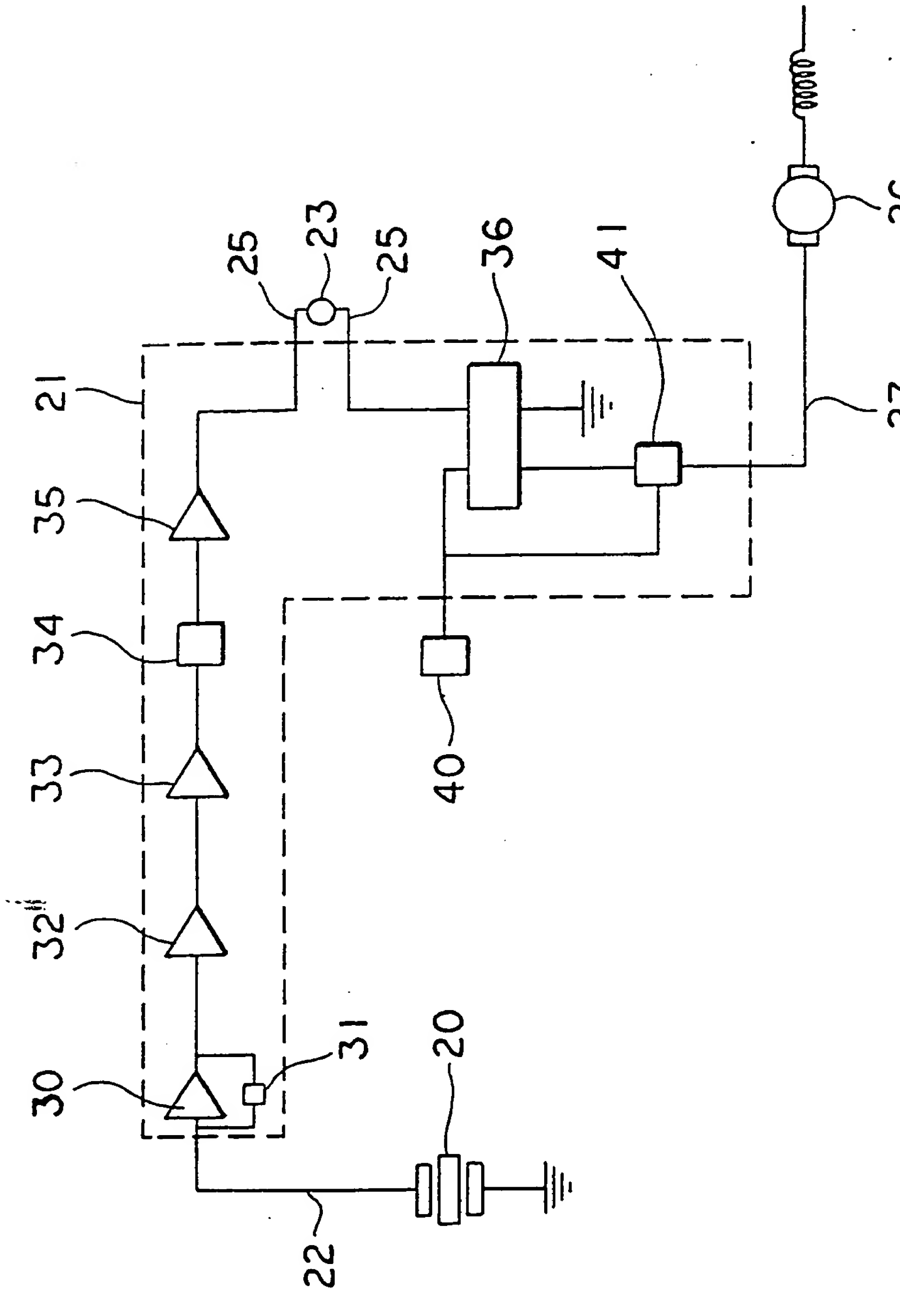

FIG. 3

Vacuum Cleaners Having Dirt Sensors

The present invention relates generally to vacuum cleaners and more particularly, to a vacuum cleaner having a sensor for detecting the presence of dirt in an airflow passageway therein.

Vacuum cleaners are widely used to clean dirt and debris from carpets, fabrics and various other materials and surfaces. A vacuum cleaner generates a flow of air through a passageway one end of which defines an inlet and is presented to the vicinity of the dirt and debris. The airflow generated by the vacuum cleaner carries the dirt and debris into the passageway inlet subsequently to be trapped or collected in a suitable container or bag for subsequent disposal.

A problem associated with using a vacuum cleaner is determining when the area being cleaned is substantially free of dirt and debris. Generally, on bare surfaces, the operator can visually inspect the area and determine whether further cleaning is necessary. For carpeting, fabrics and other surfaces, however, the dirt may not easily be visible to the operator; instead it may be trapped within the carpet fibres or the like. The operator, then, can merely operate the vacuum cleaner over an area for a period of time believed to be sufficient to remove the dirt and debris. Depending on the particular situation, however, the time period may be inadequate, resulting in dirt and debris being left in the carpet or the like. Alternatively, the time period may be unduly protracted, which results in an inefficient use of time and energy to clean a particular area. This may also

result in increased wear of the carpet itself.

In addition to the foregoing, it may be desirable to regulate the operation of the vacuum cleaner in response to the presence of dirt and debris. For mildly soiled areas, the cleaner may be operated at a reduced power setting to conserve energy and to lessen wear of the cleaner components as well as of the carpet or the like. When heavily soiled areas are encountered, it may be desirable to increase the power of the cleaner to extract the dirt and debris more effectively. After such area is cleaned, the power setting can again be reduced.

In the past, the selection of the various power settings of the cleaner has been controlled by the operator. However, as discussed hereinabove, the ability of the operator to detect dirt and debris on many surfaces significantly is limited, such that the cleaner often is operated at less than optimum power levels for the areas being cleaned.

Efforts have been proposed to assist the operator in detecting whether dirt and debris is being extracted from the area being cleaned. Such efforts include providing a thin diaphragm within an opening in the wall of the vacuum cleaner airflow passageway, preferably at a bend in the passageway. The diaphragm is so constructed and positioned that particles passing through the airflow passageway impinge against the diaphragm thereby creating an audible sound. The operator listens for such audible sound as an indication that dirt and debris are being removed from the area. The operator may then continue cleaning the area until the audible sound ceases, indicating the area is clean. Similarly, the operator can control the

power setting of the cleaner, as heretofore discussed, in response to the audible sound created by the dirt and debris impinging against the diaphragm.

While the foregoing system may be helpful in detecting dirt and debris, it is ineffective due to several inherent shortcomings. Specifically, the system requires the diaphragm to be exposed directly to the airflow through the passageway. This requires a special mounting and/or amplifying assembly resulting in a more cumbersome, complex and expensive passageway. Furthermore, such direct exposure significantly increases the risk that the thin membrane of the diaphragm may be damaged by heavier or sharp objects carried into the passageway by the airflow.

The prior system also requires the diaphragm to be positioned near the user, to enable the user to hear the audible sound over the cleaner and other environmental noises. Accordingly, such a system may be usable with canister-type cleaners but not with conventional upright cleaners. Furthermore while heavier material, such as sand, may produce a recognisable sound upon impinging the diaphragm, other lighter material, such as dust, would be less able to produce such a sound. Indeed, some material impacting the diaphragm may generate sound waves outside the frequency range of the human ear. Accordingly, the operator remains uncertain whether or not the specific area has been thoroughly cleaned.

Attempts to detect dirt in the airflow using photoelectric sensors also have proved ineffective. It is difficult to calibrate the sensitivity of such sensors accurately to detect heavier sand as well as fine dust and talc. Furthermore, the sensor must be

exposed to the airstream with the attendant risk of damage to the sensor components. An additional shortcoming of this system is found in the occlusion of the sensor from accumulated dirt film after a period of operation of the cleaner. Once occluded, the sensor becomes ineffective to detect dirt in the airflow.

Despite the attempts to provide a vacuum cleaner which enables the operator to determine the cleanliness of a particular area, none has yet resulted in a cleaner which provides a reliable dirt indicator easily identifiable by the operator. Furthermore, no system has provided a control for the operation of the cleaner in response to the existence of dirt and debris encountered in the area being cleaned.

It is, therefore, a primary object of the present invention to provide a vacuum cleaner having a sensor which reliably indicates the presence or absence of dirt and debris being removed from an area being cleaned.

According to one aspect of the present invention, a vacuum cleaner comprises suction means for creating an airflow for transporting dirt from a surface being cleaned, duct means for conveying the dirt laden airflow therethrough, and sensing means responsive to interaction between the duct means and the dirt flowing therethrough for producing a first electrical signal representative of dirt within the airflow.

According to another aspect of the present invention, a method for controlling the operation of a vacuum cleaner having a motor for creating an airflow for transporting particulate matter through an air duct, comprises the steps of generating a first electrical signal responsive to the presence of

particulate matter in the airflow; processing the first electrical signal; establishing preselected parameters for the first electrical signal; and generating a second electrical signal when the first electrical signal meets the preselected parameters.

The invention thus makes possible a vacuum cleaner having a sensor which is not exposed to the airflow in the passageway of the cleaner and in which the sensor may be located remote from the operator while generating a signal perceivable by the operator.

Preferably, the operation of the cleaner is controlled, at least in part, by the signal generated by the sensing means.

The sensing means may take various forms but preferably is a piezoelectric sensor arranged to detect vibrations set up by the passage of dirt through the duct. These vibrations may be in the form of the sound of the air in the airflow or mechanical from the impact of the dirt particles against the interior surfaces of the duct. Alternatively, the sensing means may sense electrostatic charge created by movement of the air through the duct.

Preferably, there are processing means to receive the first electrical signal and to generate a second electrical signal when the first electrical signal meets preselected parameters. For example, the preselected parameters may include the first electrical signal having a pulse amplitude of at least 24 millivolts and a pulse width of approximately 50 microseconds and may include the first electrical signal having at least three pulses within an interval of approximately ten seconds.

The invention may be carried into practice in

various ways but one vacuum cleaner embodying the invention will now be described by way of example with reference to the accompanying drawings, in which:

Fig. 1 is a perspective view of the vacuum cleaner with parts thereof broken away to depict a mounting location for a dirt sensor;

Fig. 2 is an enlarged, fragmentary cross-section of the air duct of the vacuum cleaner depicted in Fig. 1; and,

Fig. 3 is a schematic block-diagram for a circuit for processing the signal of the sensor employed by the vacuum cleaner depicted in Fig. 1.

The vacuum cleaner 10 shown in Figure 1 is of the kind known as an upright cleaner and includes a base 11, and an upper housing 12 and handle 13, together pivotally connected to the base 11. The base 11 houses a cleaner motor, an intake airflow duct and a nozzle with an opening beneath the base 11 to engage the floor. Contained within the upper housing 12 is a substantially rigid exhaust airflow duct 14 which connects the exhaust port of the cleaner motor with a filter bag 15 contained within a cleaner jacket 16.

The specific arrangement of the internal components of the cleaner 10 can be considered, in greater detail, with reference to Fig. 2. Specifically, a sensor or transducer 20 is secured to the air duct 14, and preferably to the outer surface thereof. The transducer 20 may be one of a variety of sensors which accurately detect acoustical and/or mechanical vibrations in the frequency range of approximately 3 KHz to approximately 20 KHz or higher. It has been found that an acceptable transducer 20 can be fabricated from thin-film piezoelectric material,

such as polyvinylidene fluoride (PVDF) film, having a thickness of approximately 20 μm. The PVDF film is metallized on both sides and electrically poled during manufacture. A suitable transducer 20 may be constructed from Pennwalt "KYNAR" Piezo Film, 28 μm thickness, available from Pennwalt Corporation, King of Prussia, Pennsylvania ("KYNAR" is a trade mark of Pennwalt Corporation). The planar area of the transducer 20 will depend upon the specific application; but a transducer 20 measuring approximately 0.75 inch (1.9 cm) by 1.375 inches (3.5 cm) has been found to produce acceptable results.

The transducer 20 preferably is adhesively mounted to the air duct 14. While a number of different adhesives may be usable, it is desired that an adhesive be selected which will provide a secure mechanical bond between the transducer 20 and air duct 14. Additionally, the adhesive bond should not impede the transmission of acoustical stimuli to the transducer 20, as will be appreciated hereinbelow. For this purpose, a thin layer of silicone adhesive, approximately 2 mils (0.05 mm) thick, such as RTV Silicone Adhesive/Sealant, available from General Electric Co., Waterford, New York, has proved to be quite acceptable.

The location of the transducer 20 on the air duct 14 will depend upon the specific application and may be located on the interior or exterior of the air duct 14, although as discussed hereinabove, the exterior of the air duct 14 is preferred. The transducer 20 may be located upstream of the cleaner motor, near the nozzle inlet or, as described, it may be located downstream of the motor, near the bag outlet of the air duct 14. In

the cleaner being described, the transducer 20 is mounted on the exterior surface of the air duct 14 approximately at the midpoint of the outside arc of a 90° elbow although other locations may be acceptable. Such a location, on an air duct 14 having a wall thickness of between 0.020 and 0.030 inch (0.5 and 0.8 mm), has been found to enable the transducer 20 accurately to detect the presence of dirt and debris passing through the air duct 14, as will be appreciated hereinbelow.

Located elsewhere within the vacuum cleaner 10 and preferably in the proximity of the air duct 14 within the upper housing 12 is a control module 21. In this example, the control module 21 is mounted adjacent the handle 13 within the upper housing 12; but, again, the specific location may vary depending upon the particular cleaner. The control module 21 is electrically interconnected with the transducer 20 by an input lead 22. As will be appreciated hereinbelow, the control module 21 is suitable for controlling the operation of the cleaner 10 in response to the signal received from the transducer 20.

An indicator light 23 may be mounted in the upper wall 24 of the housing 12 and is electrically interconnected with the control module 21 by leads 25. The indicator light 23 preferably is a low voltage, low current draw indicator, such as a light emitting diode (LED), which is controlled by the module 21 to indicate the passage of dirt and debris through the air duct 14; as will be discussed hereinbelow. It should be noted that the indicator light 23 need not necessarily be an LED as other visual or audible signalling devices are likewise contemplated. Furthermore, the indicator

light 23, or any other signalling device, may be omitted completely and, instead, the module 21 may be used only to control the operation of the cleaner 10, as will be appreciated hereinbelow.

The control module 21, and specifically the circuit logic thereof, can be more fully appreciated with reference to Fig. 3. The control module 21 is represented generally by the broken line and is shown interconnected with the transducer 20 through the input lead 22, with the indicator light 23 through the leads 25, and with a cleaner motor 26 through a motor lead 27. As configured, the control module 21 is capable of activating the indicator light 23 and controlling the performance of the motor 26 in response to the presence of dirt and debris in the air duct 14 as sensed by the transducer 20. It should be appreciated that many different circuits can be assembled for the control module 21 by one skilled in the art of electronics.

The output signal from the transducer 20 is a low voltage AC signal. This signal is received and amplified by a first conventional signal amplifier 30. A gain adjuster 31 may be interconnected with the first signal amplifier 30 to provide sensitivity adjustment. In such manner spurious signals from the transducer 20 can be reduced such that only signals indicative of dirt and debris in the air duct 14 are processed by control module 21.

The amplified signal of the first amplifier 30 is received by a second conventional signal amplifier 32. This re-amplified signal is then introduced to a typical pulse stretch amplifier 33 which increases the pulse width of the signal for further processing. Specifically, the signal from the first amplifier 30

may have a pulse width of approximately 50 to 160 microseconds which can then be increased with the pulse stretch amplifier 33 to a pulse width of approximately 5 to 20 milliseconds.

The signal from the pulse stretch amplifier 33 is received by an integrator/timer 34 suitable to activate the system in response to recurring signals of sufficient duration which are indicative of a sustained presence of dirt in the air duct 14. Thereafter, the integrator/timer 34 maintains activation of the system for a preselected time interval following termination of the signal generated by the sensor 20. This avoids repetitive activation/deactivation of the system with each passing signal. The system can be set to activate when approximately three to five pulses are sensed within an interval of approximately ten seconds. These parameters generally are indicative of sustained concentration of dirt in the airflow through the air duct 14. The time interval after activation of the system may vary with the particular applications; but a range of approximately one to five seconds has been found to be acceptable with a period of approximately three seconds being preferred. The time interval may be variable to the user or, more preferably, it may be fixed at the time of assembly of the cleaner 10.

The output signal from the integrator/timer 34 is once again amplified by a conventional driver amplifier 35 which amplifies the signal to generate a usable output signal. Such output signal preferably is approximately 3.0 to 4.5 volts, D.C., which may then be used to power the indicator light 23, as heretofore described. Similarly, the output signal may be directed to other components to control the operation

of the cleaner 10 as will be discussed hereinbelow.

The combination of the four amplifiers, 30, 32, 33 and 35, respectively, which define the signal processor, may be contained on a single integrated circuit (IC) for ease of manufacturing. One particular IC which has been found to be quite acceptable is a National Semiconductor LM324 quad op amplifier, although it will be appreciated that other IC's, singly or in combination, as well as individual components thereof, may be used to achieve the same operation for control module 21.

The aforesaid output signal from the driver amplifier 35, in addition to, or as an alternative to, energising the indicator light 23, may be interfaced with other components to control the operation of the cleaner 10, as, for example, regulating the speed of the cleaner motor 26. Specifically, the output signal may be fed to a conventional switching device such as an infrared switch 36, or any other suitable device which preferably permits isolation of the sensor signal from the motor circuit, as would be well known to the skilled artisan. A particular infrared switch 36 which has been found to be acceptable is a Motorola MOC3010 opto coupler.

The infrared switch 36 is interconnected to a power supply 40 adequate for the cleaner motor 26. A motor controller 41 may be interconnected in series with the infrared switch 36 to control the speed of the motor 26. Specifically, the controller 41 may be any of a number of suitable control circuits known in the art, such as a conventional, low cost, triac control circuit suitable to switch the motor 26 between low speed and high speed operation. Accordingly, when

interconnected with the infrared switch 36, the motor controller 41 will switch the operating speed of the motor 26 in response to the presence or absence of an output signal from the driver amplifier 35 which, as indicated hereinabove, is directly related to the sustained presence of dirt and debris flowing through the air duct 14 of the cleaner 10.

The foregoing description may be more fully understood and appreciated by considering the operation of the vacuum cleaner 10. Specifically, the motor controller 41 is able to regulate the power input to the motor 26 to operate normally at approximately 60 percent of full power. It should be appreciated that this low power setting is determined in relation to the nominal power required to allow the cleaner 10 to lift dirt effectively from the surface being cleaned; and that such a setting will vary for different types of cleaners.

As dirt is drawn into the unit and discharged through the air duct 14, its presence is detected by the transducer 20. Tests have revealed that the transducer 20 is capable of detecting dirt acoustically, by detecting the sound of the dirt in the airflow; mechanically, by detecting the vibrations from the impact of the dirt particles against the interior surfaces of the air duct 14; and electrostatically, by sensing the electrostatic charge created by the movement of the dirt through the air duct 14. In response to the presence of the dirt, the transducer 20 generates an AC signal of approximately 70 to 120 millivolts, which has been found to be sufficient to trigger the control module 21.

When the signal from the transducer 20 meets or

exceeds the aforesaid parameters of three to five pulses within a ten second interval, the control module 21 increases the power input to the motor 26 to increase the cleaning effectiveness of the cleaner 10.

The motor 26 will continue operating at the elevated power setting as long as dirt and debris in the air duct 14 are sufficient to generate signals within the aforesaid parameters. Then module 21 will maintain the increased power setting of the motor 26 for approximately three seconds following reduction of dirt concentration in the air duct 14, as discussed hereinabove. Following this, the control module 21 will switch to the lower power setting for the motor 26. The system will remain in this condition until dirt of sufficient concentration again is sensed in the air duct 14.

It has been found that the sensitivity of the system may reasonably be such that the control module 21 will trigger at low frequency signals, such as signals in the 2-3 KHz range. However, these signals may be associated with line voltage interference, motor vibrations and the turbulent flow of air through the air duct 14. Typical filters may be employed to eliminate such nuisance signals thereby avoiding false triggering of the module 21. Furthermore, the amplitude sensitivity of the system may be adjusted using the gain adjuster 31, as discussed hereinabove to allow activation of the system at signal amplitudes of approximately 70 millivolts or less. In this manner, the module 21 may be suitably adjusted to trigger only on filtered signals generated by the transducer 20 as a result of dirt of preselected concentration flowing through the air duct 14.

Tests have revealed that granular dirt, such as sand, may produce signals having a pulse amplitude of approximately 80 millivolts, with a pulse width of 50 microseconds, which is quite sufficient to trigger the module 21. However, if desired, the sensitivity parameters of the system may be increased to the extent that signals having a pulse amplitude of approximately 24 millivolts, and a pulse width of approximately 50 microseconds, will trigger the module 21. This would generally be sufficient to trigger the module 21 in the presence of fine dirt and dust particles. However, at this sensitivity level adequate signal filtering means, as discussed above, may be necessary to eliminate false triggering of the control module 21 by low frequency signals caused by extraneous sources in the cleaner, as may be known to one skilled in the art.

While the foregoing is a description of one embodiment of the invention, by no means does it constitute the exclusive embodiment. For example, the invention may be incorporated into other types of vacuum cleaners, such as canister cleaners. Furthermore, the sensor may be positioned at other locations throughout the dirt path to sense the flow of dirt; and more than one sensor may be employed, or more than one type of sensor, to extend the sensitivity range for sensing dirt. Also, alternative electronics may be employed to process the signal from the sensor to produce a usable output signal. Then, too, means may be provided in the form of a switch, for example, to override or disconnect the system, and allow the cleaner to function in a conventional manner.

It should be appreciated that the present invention provides an effective indication of cleaner

operation and/or closed-loop control for the motor 26 of the cleaner 10. Such a system allows for highly efficient cleaner operation and efficient utilisation of operator efforts in vacuuming carpets or other surfaces.

The overall durability of the cleaner 10 is improved due in part to the fact that the cleaner 10 is operated more often at low power with only intermittent periods of high speed operation. The life of the cleaner motor, bearings, brushes and other components may be increased significantly as a result of the low power operation. These critical components can be designed to less demanding standards, resulting in less expensive assemblies. Furthermore, the carpet itself is exposed to less wear because of the generally lower operating speed of the cleaner 10.

It should also be appreciated that a cleaner embodying the present invention greatly assists the operator in cleaning. By means of a perceptible indicator, such as a light, and/or change in operation of the cleaner motor, the operator can identify when a dirty area is encountered. The operator can then continue cleaning in the identified area until the cleaner indicates that dirt is no longer being removed therefrom. Thereafter, the operator may proceed to an area that has not been cleaned without expending undue time. Additionally, with the cleaner generally operating at a lower power level, the operator is less exposed to the noise and vibration generated by the cleaner at higher operating levels, thus reducing the fatigue of the operator.

Although the foregoing has considered a cleaner operating normally at a lower speed, it is likewise

contemplated for the cleaner normally to operate at a higher speed with intermittent periods of lower speeds. In this fashion, the operator may clean a given area quickly at high speed operation but, when sensor 20 detects dirt, the cleaner may switch to a lower speed so as to avoid damaging internal components of the cleaner by heavy particles of dirt and debris. When such heavy concentration of dirt has been reduced, the cleaner, again, may return to high speed operation.

Claims:

1. A vacuum cleaner comprising suction means for creating an airflow for transporting dirt from a surface being cleaned, duct means for conveying the dirt laden airflow therethrough, and sensing means responsive to interaction between the duct means and the dirt flowing therethrough for producing a first electrical signal representative of dirt within the airflow.

2. A vacuum cleaner as claimed in claim 1 which includes processing means to receive the first electrical signal and to generate a second electrical signal when the first electrical signal meets preselected parameters.

3. A vacuum cleaner as claimed in claim 2 which includes controller means to receive the second electrical signal and to regulate the suction means in response thereto.

4. A vacuum cleaner as claimed in claim 3 in which the suction means is an electric motor and the controller means regulates the operation thereof.

5. A vacuum cleaner as claimed in claim 2 or claim 3 or claim 4 in which the preselected parameters include the first electrical signal having a pulse amplitude of at least 24 millivolts and a pulse width of approximately 50 microseconds.

6. A vacuum cleaner as claimed in claim 5 in which the preselected parameters include the first electrical signal having at least three pulses within an interval of approximately ten seconds.

7. A vacuum cleaner as claimed in any of claims 2 to 6 in which the processing means includes timer means to maintain generation of the second electrical signal for a preselected period of time following termination of the first electrical signal to meet the preselected parameters.

8. A vacuum cleaner as claimed in any of claims 2 to 7 which includes indicating means responsive to the second electrical signal.

9. A vacuum cleaner as claimed in claim 8 in which the indicating means is an indicator lamp.

10. A vacuum cleaner as claimed in any preceding claim in which the sensing means is affixed to the duct means and is physically displaced from the airflow.

11. A vacuum cleaner as claimed in any preceding claim in which the sensing means is an acoustical transducer.

12. A vacuum cleaner as claimed in any preceding claim in which the sensing means is a piezoelectric transducer.

13. A vacuum cleaner constructed and arranged to operate substantially as described herein with reference to the accompanying drawings.

14. A method for controlling the operation of a vacuum cleaner having a motor for creating an airflow for transporting particulate matter through an air duct, comprising the steps of: generating a first electrical signal responsive to the presence of particulate matter in the airflow; processing the first electrical signal; establishing preselected parameters for the first electrical signal; and generating a second electrical signal when the first electrical signal meets the preselected parameters.

15. A method as claimed in claim 14 which includes the step of generating a user identifiable signal in response to the second electrical signal.

16. A method as claimed in claim 15 in which the user identifiable signal is provided by an indicator lamp.

17. A method as claimed in claim 14 or claim 15 or claim 16 which includes the step of regulating the airflow through the air duct in response to the second electrical signal.

18. A method as claimed in claim 17 in which the step of regulating the airflow includes controlling the operation of the motor.

19. A method as claimed in any of claims 14 to 18 in which the step of generating a first electrical signal includes affixing a transducer to the air duct at a location physically displaced from the airflow, and exciting the transducer by passing particulate matter through the air duct.

20. A method as claimed in any of claims 14 to 19 which includes the step of maintaining generation of the second electrical signal for a preselected period of time following termination of the first electrical signal to meet preselected parameters.

21. A method of controlling the operation of a vacuum cleaner substantially as described herein with reference to the accompanying drawings.

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